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B CENTRIFUGAL SEPARATOR

~~Centrifugal Separator~~

B BACKGROUND

This invention relates to centrifugal separators of the self-powered kind for separating particulate contaminants from a liquid, such as a vehicle engine lubricant, within a containment rotor to which contaminated liquid is supplied at elevated pressure, and particularly, but not exclusively, relates to low-cost disposable rotors for use with passenger automobile engines.

Self-powered centrifugal separators are well known for separating fluids of different densities or for separating particulate matter from liquids and have long been used in lubrication systems for engines and analogous items of vehicles. Such devices are described in, for example, GB 735658, GB 757538, GB 2160796, or GB ~~2383194~~ 2283694.

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The common principle of operation is that a housing contains a rotor which is supported therein to spin at high speed about a substantially vertical axis. The rotor comprises a container to which contaminated liquid lubricant is supplied at elevated pressure along the axis of rotation at one end of the rotor and is ejected from tangentially directed reaction jet nozzles at the

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other end of the rotor into the housing from which it drains to the engine sump. The energy lost by the ejected liquid effects rotation of the rotor about the axis at a speed, in excess of 8,000 rpm, fast enough for the liquid circulating in, and passing through, the rotor to deposit solid contaminants on radially outward surfaces. For efficient separation, and to ensure that separated contaminants do not interfere with the reaction jet nozzles, the rotor container is provided with a radially inwardly extending partition wall that effectively divides the rotor into a separation chamber, in which the solids collect, and an outflow chamber, to which the cleaned liquid passes by way of a transfer aperture sited near the rotation axis. It is common in modern designs, such as, EP 0193000 and GB 2283694, for this partition wall to extend both radially and axially as what is sometimes referred to as a separation cone, which better holds solids and liquid-containing sludge within the separation chamber if the rotation axis is tilted from the vertical.

There are several criteria associated with successful operation. Lubricant supplied to the rotor has to be available at a significant pressure if the energy lost by its passage through the reaction jet nozzles is to be sufficient to rotate the rotor fast enough to effect centrifugal separation of said contaminated particles. Also, of course, the lubricant passed through the centrifugal separator loses substantially all of its energy in effecting rotation by jet reaction, that is, it is returned directly to the sump and by-passes the normal lubrication utilisation circuits of the engine, so that the centrifugal separator operates in a so-called lubricant by-pass mode. Consequently, there is normally incorporated in the lubricant supply system a pressure responsive valve which inhibits the flow of lubricant to the centrifugal separator when the supply pressure is below a predetermined level at which the engine might be starved of lubricant if any were diverted and at which the rotor would not operate efficiently even if supplied.

Such a centrifugal separator is normally associated with a conventional full-flow, or through-flow, filter (although the

small particle separation capabilities of the centrifugal separator enables a rather coarser mesh filter to be used than otherwise) and it is often arranged that both filter and separator are mounted on a specially designed interface which includes supply ducts and pressure responsive flow control valves, for example as shown in GB 2160449 and GB 2160796.

Diesel engines are particularly well suited to this form of lubricant cleaning, because of problems of small, light particles in the lubricant that result from combustion products and the generally longer intervals between servicing operation than has been normal with gasoline engines. Thus the combination of a coarse mesh, full-flow filter and centrifugal separator is particularly suited to operation of, and has been widely adopted with, commercial vehicles to maximise intervals between servicing operations.

More recently, it has become popular to include similar diesel engines in small passenger vehicles and, irrespective of engine type, for there to be longer intervals between servicing at which lubricant and/or filter elements would be changed, it being conventional now in relation to passenger vehicles that contaminated components of such filter elements are disposable rather than cleanable by the servicing mechanic, who is frequently the vehicle owner.

Thus it follows that in adapting the concept of supplementing a full-flow filter with a centrifugal separator to such small passenger vehicles, the rotor, when it does eventually fill with contaminant, should be disposable and replaceable with a new one rather than cleaned, and notwithstanding the increased interval between replacements, the disposable rotor must be a low cost item. To this end low cost disposable rotor designs exist, for example EP 0193000, and GB 2283694 which rely upon the rotor being formed as a canister from pressed sheet materials.

However, it is found that centrifugal separators, particularly

those of such a pressed sheet construction, exhibit characteristics peripheral to their separation functionality which may militate against ready acceptance within the small passenger vehicle environment.

In such passenger vehicles, although the passenger compartment is much closer to the engine and its ancillary components, there is required a much lower noise level than for commercial vehicles. Whereas any additional noise level caused by a spinning centrifugal separator rotor may be considered minimal in terms of passenger perception whilst the engine is running, it is found that an increased noise level continuing after the engine is stopped is particularly objectionable.

When the engine is stopped the centrifuge rotor, which may be spinning up to 10,000 rpm, continues to rotate for a considerable deceleration or wind-down period that may be in the range of 30-60 seconds or even up to 90 seconds, depending upon the supply pressure and temperature of lubricant passing therethrough, and during that wind-down period the noise level may increase as the rotor empties of lubricant and exhibits bearing contact and out-of-balance vibration as the speed falls and the bulk of the liquid moves about within the partially filled container.

The centrifuge rotor is usually mounted for rotation by bearings comprising plain, parallel bushes carried at each end of the rotor and surrounding fixed, vertically extending axle means to form journal bearings.

The bushes are a clearance fit on the axle means to permit unimpeded rotation and the gap between each bush and axle means is exposed to the lubricant supplied to the rotor such that some lubricant escapes along the gap and with the rotation creates a hydrodynamic film that provides easy rotation and significant radial stiffness. Furthermore, it is known to make use of the forces exerted axially on the bushes and rotor, due to exposure of the ends of the bushes to fluid pressure, to counter the effect of gravity pulling the rotor downwardly along the axle means by

having the upper bush of smaller diameter than the lower bush whereby the lubricant pressure acts on different areas to lift the rotating rotor. Each of said bushes may therefore also comprise a radially extending flange to bear against an axially facing surface of the housing, as a pressure lift thrust bearing at the upper part of the housing to limit lifting of the rotor and (particularly) as a weight thrust bearing at the lower part of the housing to support its weight in the absence of lubricant pressure.

It will be appreciated that such weight thrust bearing is employed each time that the lubricant supply is stopped and the weight of the rotor is not countered by lubricant supply pressure. Furthermore, it will be appreciated that the supply of lubricant to the journal bearing gaps also effectively ceases with lubricant supply so that as the rotor winds down, the radial bearing stiffness ceases, permitting the rotor to vibrate on the bearings, both journal and thrust, with the transmission of noise by way of the housing to the engine.

The vibration may be exacerbated as the balance of the rotor is affected by way of lubricant draining therefrom and not being replenished.

To the extent that wind-down noise results from such draining of the rotor, co-pending application number GB9511812.1 describes a flow check valve to retain lubricant within the centrifuge rotor.

However it does not address the problem of wind-down noise resulting directly from the reduction in bearing stiffness as the and hydrodynamic film between bushes and axles means disrupts when the lubricant pressure subsides.

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SUMMARY OF THE INVENTION

It is an object of the present invention to provide a centrifugal separator in which vibration on wind-down due to bearing structure is mitigated.

According to the present invention, a centrifugal separator

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comprising a housing, axle means extending along the housing substantially vertically and defining a rotation axis, a rotor rotatable about the rotation axis about said axle means and including at each end thereof a bush surrounding the axle means defining a journal bearing, each said bush being exposed to lubricant supplied to the rotor such that lubricant can pass between said bush and axle means to form therein a film, at least one of the bushes providing weight thrust bearing means operable to support the weight of the rotor, at least during wind-down, the weight thrust bearing means comprising at least one portion of said axle means tapering from a lower region of greater diameter to an upper region of lesser diameter and said bush surrounding the portion conforming to the taper, defining a combined journal and thrust bearing whereby the rotor carried by the thrust bearing is supported both radially and axially.

Preferably the end of the upper bush exposed to lubricant pressure is a lesser diameter than the upper end of the lower bush such that normal lubricant supply pressure acts to separate the cooperating taped surfaces of the weight thrust bearing means.

Preferably the weight thrust bearing means is defined in both upper and lower bushes.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings. ~~in which:-~~

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B >BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a sectional elevation through a first embodiment of self-powered centrifugal separator in accordance with the invention showing a novel weight thrust bearing formed between the lower rotor bush and the tapered spindle,
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Figure 2 is a sectional elevation through a second embodiment in which the weight thrust bearing is formed at the upper bush, and

Figure 3 is a sectional elevation through a third embodiment in which the thrust bearing is formed in both upper and lower bushes.

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> DETAILED DESCRIPTION OF THE DRAWINGS

Referring to Figures 1 and 2, a self-powered centrifugal separator arrangement for a vehicle engine, particularly a small passenger vehicle, is indicated generally at 10. The separator is employed in conjunction with a full flow filter (not shown) in maintaining the engine lubricant free of potentially damaging contaminants. Lubricant is pumped around the engine by a pump (not shown) whose delivery pressure is regulated but also, to a limited extent, dependent upon engine speed and lubricant temperature.

The separator arrangement 10 comprises a housing 11 in the form of a support structure 12 coupled to the engine to receive pumped lubricant by way of supply duct 13 and return it to the sump by way of drain duct 14, thereby by-passing the engine components which use the pumped lubricant. The support structure 12 has fixed thereto a substantially vertically extending axle means 16 in the form of a spindle which has a passage 17 extending at least part way along and coupled to the supply duct 13 at its lower end. The housing is in vertically separable parts 18_1 and 18_2 and the upper end of the spindle 16_1 is secured to, and secures, a housing part 18_2 releasably sealed to the part 18_1.

A rotor 20 is mounted within the housing for rotation about the spindle 16. The rotor is substantially conventional in comprising a container formed from pressed steel sheet components 21 and 22 jointed at a folded seam 23. The component 21 has a peripheral wall 24 which extends radially inwardly at one end of the rotor to an aperture 25. The component 22 forms a substantially radially extending base in which are found recesses 26, 27 containing a pair of tangentially direction jet reaction nozzles, one only of which is visible at 28, the base component being apertured at 29 in line with aperture 25 on the longitudinal axis of the rotor.

A hollow member 30 extends between and through the axially spaced apertures 25 and 29, being swaged to the container components to act as a spacer for the end walls and a receptacle for bearing bushes 31 and 32 which support the rotor for rotation about spindle 16, the longitudinal axis of the rotor therefore being

synonymous with the rotation axis of the rotor.

The spindle passage 17 opens into the spacer member, which is apertured at 33 to admit liquid lubricant at supply pressure to the container from the rotation axis. The spacer member 30 thus forms a radially inner wall for the container.

Within the container, internal partition wall 35 extends radially inwardly from the peripheral wall at the seam 23 and divides the container into a separation chamber 36 (in which contaminants are separated from the liquid lubricant) and an outflow chamber 37 in communication with the reaction nozzles, 28 etc. The radially inner periphery ~~38~~ of the partition wall defines a transfer aperture 39 between the separation and outflow chambers 36 and 37. The partition wall 35, although extending radially inwardly is also inclined with respect to the rotation axis at an acute angle being frusto-conical in elevation, the arrangement serving to inhibit solid contaminants which tend to collect within the radially outer peripheral wall from falling into the outflow container with attendant risk of reaction nozzle blockage or return to the lubricant sump. To this end, such an inclined partition wall is frequently called a separation cone.

The upper part of the spindle 16_1 is of lesser diameter than the lower part, 16_2, such that the ends of the bushes 31 and 32 have differential face areas exposed to the lubricant pressure in tubular member 30, and thus also have forces acting thereon related to such diameter. Thus in operation a greater force acts on the upper bush 32 in an upward direction which tends to lift the rotor to counter its weight, the degree of lift being dependant on instantaneous supply pressure. Clearly if the pressure is such that the pressure-induced lift exceeds the weight of the rotor the rotor will move to contact the housing part 18_2 and to accommodate this a pressure lift thrust bearing is formed by substantially radially extending flanges 32_1 of bush 32 and static bush 38 secured to the housing part.

The rotor thus far described is essentially conventional.

The weight of the rotor is taken, except when overcome by said pressure-induced lift, by weight thrust bearing means. Conventionally such weight thrust bearing means comprises an image of the pressure lift thrust bearing, that is, radially extending flange surface to the lower end of bush 31 and upper end 12_1 of support structure 12.

However, in accordance with the present invention, weight thrust bearing means 40 comprises the lower portion 16_2 of the spindle and bush 31. The spindle portion 16_2 tapers from a lower region 41 of greater diameter to an upper region 42 of lesser diameter, the tapered region 43 having a shallow taper, that is, large included angle.

The bush 31 has a corresponding taper to a part of its internal surface such that it both surrounds the upper region 41 and the tapered region 43 of the spindle.

The tapered region thus provides a thrust bearing which supports the weight of the rotor at rest when supply pressure is below a level at which the pressure-induced lift overcomes the weight.

However, when after normal operation supply pressure ceases as the engine is stopped and the aforementioned clearances between bushes and spindles are deprived of radial stiffness from the lubricant, the weight of the rotor tends to seat it on the tapered weight thrust bearing and the tapered surfaces act also to centre the bush with respect to the spindle, that is, re-introduce an effective radial stiffness which mitigates the vibration due to bearing clearance.

It will be appreciated that the degree and form of taper is open to variation, provided the taper is shallow enough not to result in wedging effects, as is the extension of the bush axially both sides of the tapered region.

It will be appreciated that the weight thrust bearing may be defined within the upper bush as indicated in separator 10′ in

Figure 2 at 40', with modified bush form 32' and spindle portion 16_1' having cooperating tapers and the lower spindle portion and lower bush form 31' having no cooperating tapers.

Conveniently, and as shown in Figure 3 for separator 10'', the weight thrust bearing 40'' is defined within both the lower bush 31 and upper bush 32' by cooperating tapers to both the spindle end portions and the bush pores.

It will be appreciated that instead of a single continuous spindle 16 the axle means may comprise a stub spindle exiting from each end of the housing. In such arrangement, where the upper spindle portion is inserted vertically into the upper bush and not vice versa, the pressure lift thrust bearing may be formed by tapered co-operating surfaces similar to the lower weight thrust bearing.

Also, the provision of pressure-induced lift, and the corresponding pressure lift thrust bearing, may be omitted, so that the rotor normally operates in contact with the weight thrust bearing.

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